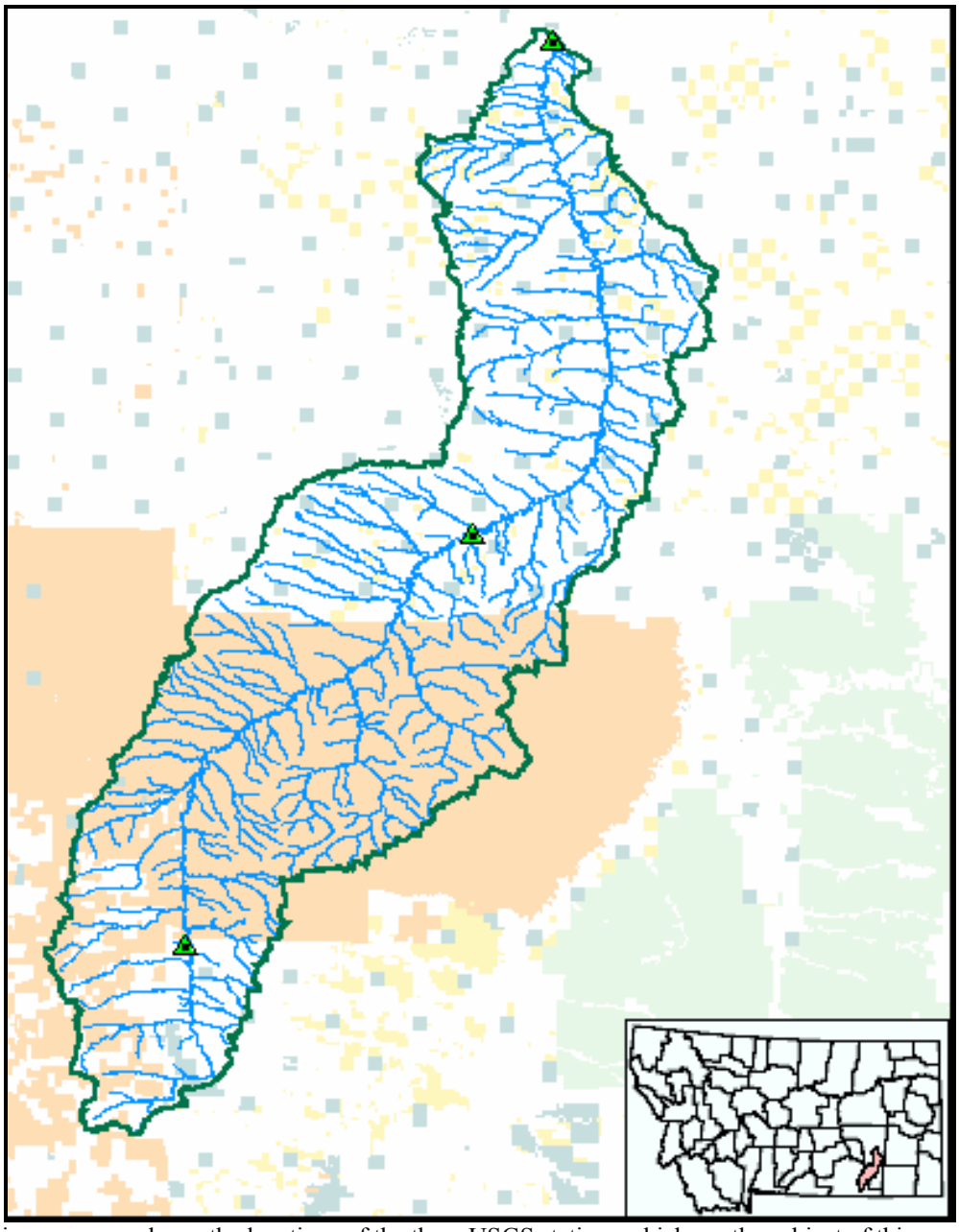
Water Year 2006
Overview of Surface Water Monitoring Data for SC, SAR and Flow in the Rosebud Creek Watershed



This cover map shows the locations of the three USGS stations which are the subject of this report.

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July, 2007

Introduction

When Coal Bed Natural Gas (CBNG) is developed, the methane must be allowed to desorb from the coal so that it can flow to production wells. This desorption is typically achieved by pumping groundwater from the coal bed aquifer to reduce the hydrostatic pressure within the coal seam (allowing the methane to desorb) and create a pressure gradient within the aquifer. This pressure gradient causes methane to flow towards the pumping wells.

CBNG water in the Montana portion of the Powder River Structural Basin (PRB) is moderately saline, having a Specific Conductance (SC) on the order of 2,000 microSiemens per centimeter at 25 degrees Celsius (μS/cm). SC is the ability for water to conduct a current at 25 degrees Celsius, and it is proportional to salinity. High salinity irrigation water may result in decreased crop yields depending on the crop being grown (See Fig. 1). The technical definition of Electrical Conductivity EC is "the ability of water to conduct a current"; however the Montana Department of Environmental Quality (MDEQ) regulations define EC as "the ability of water to conduct an electrical current at 25ºC". Since this is the same as the technical definition of SC, the SC values discussed in this report are directly comparable to the EC standards.

CBNG water in Montana is a sodium-bicarbonate (Na-HCO_3) type water, while Rosebud Creek is more balanced; having Ca≈Mg>Na and HCO_3>SO_4. This dominance of sodium cations causes CBNG water to have a high Sodium Adsorption Ratio (SAR; which is a complex ratio of Na to Ca+Mg); typically between 30 and 60 (ALL, 2001). High SAR values may cause impacts to soil structure, and impair the ability for clay rich soils to infiltrate water (see Fig. 3). There is also little sulfate in water from productive coal seams (VanVoast, 2003). Within the PRB some of the CBNG produced water managed through treated or untreated discharge to surface waters under National Pollutant Discharge Elimination System (NPDES) permits, implemented under the Clean Water Act.

In Montana, NPDES permitting is conducted by the Montana Department of Environmental Quality (MDEQ) under the Montana Pollutant Discharge Elimination System (MPDES) permit program. If discharges were to occur on the Crow Reservation NPDES permits would be needed from the EPA. If discharges were to occur on the Northern Cheyenne Reservation NPDES permits would be needed from the Northern Cheyenne Tribe, which has been granted treatment as a state status. There are currently no permits or proposals for CBNG discharge to Rosebud Creek, and no CBNG development is occurring in the Rosebud Creek Watershed.

In response to the potential for CBNG development in this area, the MDEQ and Northern Cheyenne Tribe have developed surface water quality standards for EC and SAR in the Rosebud Creek watershed. These standards provide criteria against which to compare the monitoring data. These standards are summarized in Table 1 below. It should be noted that the MDEQ standards have been reviewed and approved by the United States Environmental Protection Agency (EPA), and therefore have Clean Water Act standing. The Northern Cheyenne Tribe has been granted "Treatment as a State" (TAS) status by

the EPA; however their standards have not been approved by the EPA. Thus, the Northern Cheyenne standards do not have Clean Water Act standing. Also, note that irrigation season standards are different from the non-irrigation season, and the MDEQ and Northern Cheyenne have defined the irrigation season differently. It should be noted that these values are used solely as a point of comparison; the comparisons in this report do not constitute regulatory determinations.

The Montana Board of Environmental Review (BER) has modified the EC and SAR standards which the MDEQ uses in its permitting process; however this report only considers those standards which were in force during water year 2006. The most substantial change adopted by the BER was to designate EC and SAR "harmful" parameters. This change has not yet been approved by the EPA, and so is not in force at this time.

Table 1: MDEQ and Northern Cheyenne Surface Water Standards Applicable for Water Year 2005 for EC and SAR in the Rosebud Creek Watershed

Irrigation Season[1]					
	MDEQ		Northern Cheyenne		
	Rosebud Creek	Tributaries	Southern Boundary	Northern Boundary	Tributaries
EC (uS/cm)					
Monthly Average	1000	500	1000	1500	1500
Not to Exceed	1500	500	2000	2000	2000
SAR					
Monthly Average	3.0	3.0	---	---	---
Not to Exceed	4.5	4.5	2.0	3.0	3.0

Non-Irrigation Season[1]					
	MDEQ		Northern Cheyenne		
	Rosebud Creek	Tributaries	Southern Boundary	Northern Boundary	Tributaries
EC (uS/cm)					
Monthly Average	1500	500	---	---	---
Not to Exceed	2500	500	2000	2000	2000
SAR					
Monthly Average	5.0	5.0	---	---	---
Not to Exceed	7.5	7.5	2.0	3.0	3.0

1: The irrigation season specified by the MDEQ is from March 1st to October 31st while the irrigation season specified by the Northern Cheyenne is from April 1st to November 15th.

The Interagency working group (IWG) for CBNG has identified regional surface water monitoring stations for the Rosebud Creek watershed. These stations, with their status for water year 2006 (10/1/05-9/30/06) relative to the IWG monitoring plan are listed on Table 2 below. Table 3 provides a summary of the IWG monitoring plan, further detail is

available at http://pubs.usgs.gov/fs/2005/3137/pdf/fs2005-3137.pdf. Data collected at these stations included continuous flow, continuous specific conductance (SC), and analytical sampling. Analytical sampling includes the measurement of flow, field parameters (SC, pH, temperature, etc) and includes the collection of water-quality samples. Although these samples were analyzed by the USGS for many parameters, this report will focus on SC, SAR, and flow. SC and SAR are considered to be the parameters most likely to be affected by CBNG development (MDEQ, 2003b), and SC and SAR in the natural system fluctuate significantly with flow. The monitoring at these stations was funded by the USGS, the BLM, and the Northern Cheyenne Tribe. An expanded set of analytical data are available from the USGS at http://waterdata.usgs.gov/mt/nwis/.

Table 2: Status of Surface Water Monitoring relative to the IWG Surface Water Monitoring Plan in the Rosebud Creek Watershed, Water Year 2006
(Conducted = ●; Partially Conducted = ⊙; Not Conducted = ○)

Site	Continuous Stream-flow	Field measure-ments	Major Ions	Nutrients	Trace elements, primary	Trace elements, secondary	Sus-pended sediment
Rosebud Creek at reservation boundary, near Kirby	●	⊙	⊙	●	⊙	●	⊙
Rosebud Creek, near Colstrip	●	○	○	○	○	○	○
Rosebud Creek at mouth, near Rosebud	●	⊙	⊙	●	⊙	●	⊙

Table 3: IWG Recommended Surface Water Monitoring Plan

Constituent Class	Sampling Frequency
Streamflow	Continuous
Field Measurements	12 times per year
Major Ions	12 times per year
Suspended sediment	12 times per year
Primary Metals	12 times per year
Secondary Metals	2 times per year
Nutrients	2 times per year

Data Review

For all sites, please see the figures section for graphical display of the data. Tabulated summary statistics for the sites are provided on Table 4 below.

Table 4: Summary of USGS Monitoring Data in the Rosebud Creek Watershed for Water Year 2006

		Daily Mean		Water Quality Samples			Monthly Mean+
		Flow (cfs)	SC (uS/cm)	Flow (cfs)	SC (uS/cm)	SAR	SC (uS/cm)
Rosebud Creek at Reservation Boundary near Kirby, MT	n	365	199	8	8	7	7
	min	0.0	794	0.1	871	0.5	903
	max	39	1170	24	1150	0.9	1040
	mean	3.5	994	5	985	0.7	996
	median	1.4	1000	1.8	986	0.8	998
Rosebud Creek near Colstrip, MT	n	365	---	---	---	---	---
	min	0.0	---	---	---	---	---
	max	42	---	---	---	---	---
	mean	6.5	---	---	---	---	---
	median	4.0	---	---	---	---	---
Rosebud Creek at mouth, near Rosebud, MT	n	365	---	5	5	5	---
	min	0.0	---	3.0	1900	2.9	---
	max	206	---	32	3380	8.6	---
	mean	7.9	---	15	2512	4.4	---
	median	1.2	---	9.6	2480	3.7	---

Indicates value greater than the MDEQ Irrigation Season Standard.

+ = Monthly mean values are calculated by taking the simple mean of all mean daily and analytical values collected during each calendar month, provided that at least 9 values were collected.

SC = Specific Conductance

SAR = Sodium Adsorption Ratio

uS/cm = microSiemens per centimeter

cfs = cubic feet per second

For each station a summary of the daily mean flow, and SC, data collected during water year 2006 is presented if available. Analytical SC, SAR and flow data are also presented. Analytical samples are compared to the MDEQ "not to exceed" (NTE) surface water standards for EC and SAR. For comparison to the mean monthly EC and SAR standards the mean monthly values are calculated as the simple average of all the mean daily and analytical measurements recorded during each calendar month, provided that at least nine values were obtained. Note that within the figures section the daily mean and analytical data are combined when discussing the range of values recorded. SC vs. Flow, SAR vs. Flow, and SC vs. SAR with historical data are presented in graphical form to allow evaluation of 2006 data in context.

Since SC and SAR are dependent on flow, it is important to recognize up front that flows during water year 2006 were below long-term averages. A comparison of mean annual flow at each station vs. the period of record is shown on Table 5 below. If comparisons are to be made between water quality data from different years, it is important to also take flow into account.

Table 5: Comparison of Flows

Station Name	Annual Mean Flow (cfs)	
	WY 2006	Period of Record
Rosebud Creek near Kirby, MT	3.5	5.7
Rosebud Creek, near Colstrip, MT	6.5	21.7
Rosebud Creek, near Rosebud, MT	7.9	25.6

cfs = cubic feet per second

Rosebud Creek near Kirby

Flow and SC were measured continuously at this site for at least a portion of the year. Water-quality samples were also collected. Mean daily flow values ranged from 0 to 39 cfs, with the mean being 3.5 cfs (see Fig. 3).

Mean daily mean SC data collected at this station ranged from 794 to 1170 µS/cm, with a mean value of 994 µS/cm (see Fig. 4). Analytical SC values at this site ranged from 871 to 1150 µS/cm, with the mean being 985 µS/cm. Analytical SAR values at this site ranged from 0.5 to 0.9 with the mean being 0.7 (see Figs. 4-7).

Recorded SC values did not exceed the MDEQ or Northern Cheyenne EC not to exceed standards. Recorded SAR values did not exceed the MDEQ or Northern Cheyenne not to exceed standard. Mean monthly SC values were in excess of the MDEQ and Northern Cheyenne mean monthly EC standards during October, August, and September. Mean monthly SAR values were not calculated due to a lack of data (see Fig. 4).

SC vs. Flow, SAR vs. Flow, and SC vs. SAR charts in the figures section present the 2006 data along with historical data (see Figs. 5-7).

Rosebud Creek near Colstrip

Flow was measured continuously at this site. No analytical data were collected. Mean daily flow values ranged from 0 to 42 cfs, with the mean being 6.5 cfs (see Fig. 8).

Rosebud Creek near Rosebud

Flow was measured continuously at this site. Water-quality samples were also collected. Mean daily flow values ranged from 0 to 206 cfs, with the mean being 7.9 cfs (see Fig. 9).

Analytical SC values at this site ranged from 1900 to 3380 µS/cm, with the mean being 2512 µS/cm. Analytical SAR values at this site ranged from 2.9 to 8.6 with the mean being 4.4 (see Figs. 10-13).

Recorded SC values were greater than the MDEQ EC not to exceed standards for four of the five samples. Recorded SAR values were less than the MDEQ SAR not to exceed standard for four of the five samples (see fig 10). Mean monthly values were not calculated due to a lack of data.

SC vs. Flow, SAR vs. Flow, and SC vs. SAR charts in the figures section present the 2006 data along with historical data (see Figs. 11-13).

Conclusions

During Water Year 2006 (October 2005-September 2006) flows within Rosebud Creek watershed were lower than historical averages. EC and SAR can be correlated with flow so an evaluation of EC and SAR must also take flow into account.

A comparison to the MDEQ surface water standards for EC and SAR showed that at least one of these standards are exceeded part of the time at both stations for which there was analytical data. The uniform exceedance of these standards, even though no CBNG development has occurred in this watershed indicates that natural and/or non-CBNG conditions are responsible for these exceedances.

A statistical trend analysis was not conducted for this data; however visual inspection of the SC vs. Flow, SAR vs. Flow, and SC vs. SAR graphs does not indicate noticeable deviation from historical trends. Since new stresses have not been applied to this watershed, deviations would not be expected.

References

Ayers, R. S., and Westcot, D.W., 1985, Water Quality for Agriculture, FAO Irrigation and Drainage paper 29 (Rev 1), Food and Agriculture Organization of the United Nations.

Hansen, B.R., Gratton, S. R., and Fulton A., 1999, Agricultural Salinity and Drainage, University of California Irrigation Program, University of California, Davis.

MDEQ, 2003b, Record of Decision for the Montana Statewide Oil and Gas Environmental Impact Statement (http://www.deq.state.mt.us/coalbedmethane/pdf/RODAug7_03.pdf)

VanVoast, W.A., 2003, Geochemical signature of formation waters associated with coalbed methane, AAPG Bulletin, v. 87, no. 4 (April 2003), pp. 667–676.

Reviewers

Mike Philbin	BLM, Billings, MT
Jim Lloyd	MDEQ, Helena, MT
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Figures

Figure 1: Comparison of Crop Yield to SC (Salinity) and Recorded 2006 SC Values in the Rosebud Creek Watershed

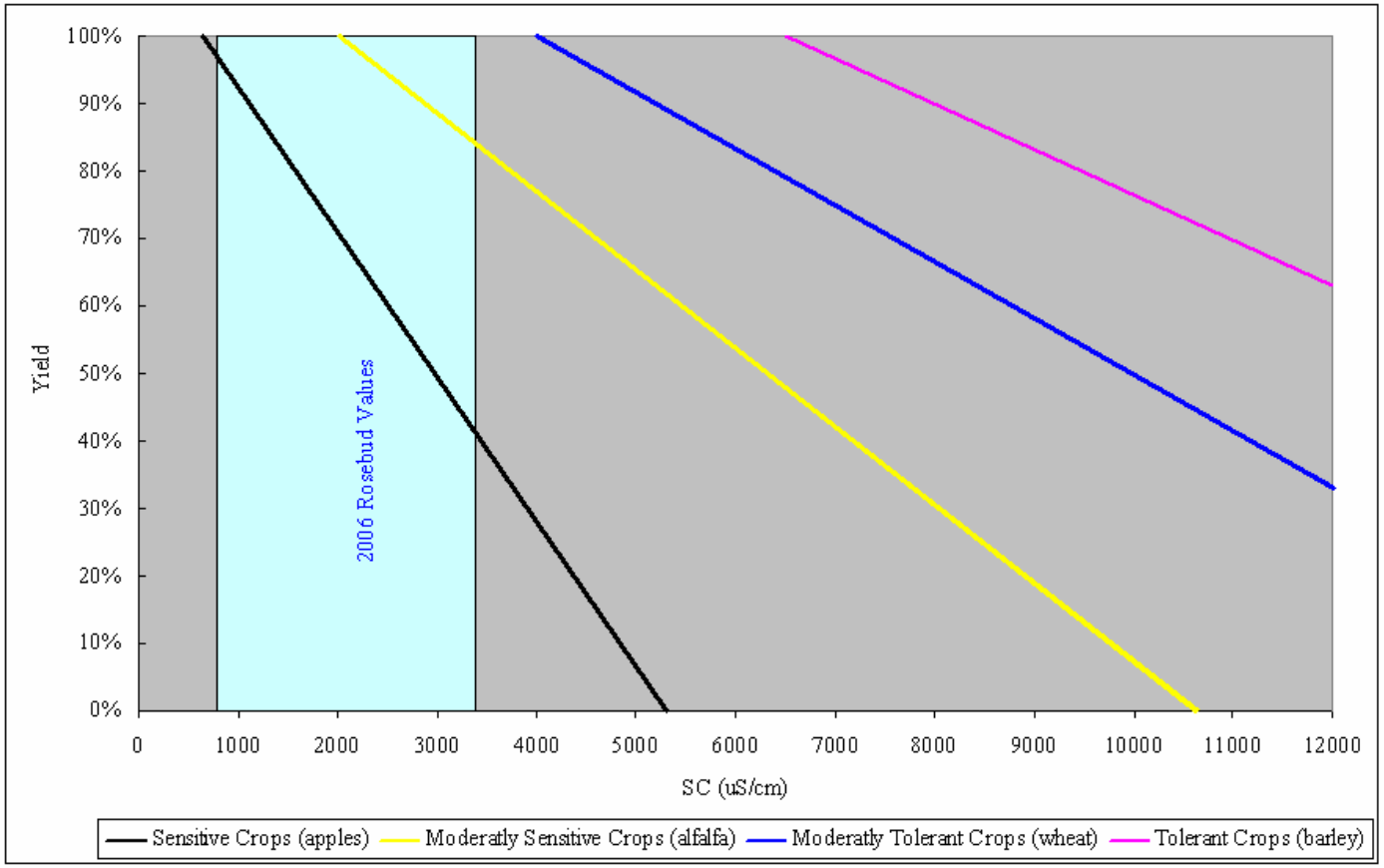

Figure 1 shows the range of SC values recorded during water year 2006 compared to yield vs. salinity curves for representative crops (Ayers and Westcott, 1985). Note that yield comparisons are made to that which would be attained using low salinity irrigation water, and assumes that all other factors are equal. Values ranged from 794 to 3380 uS/cm.

Figure 2: Comparison of Infiltration Criteria and Recorded 2006 SC and SAR Values in the Rosebud Creek Watershed

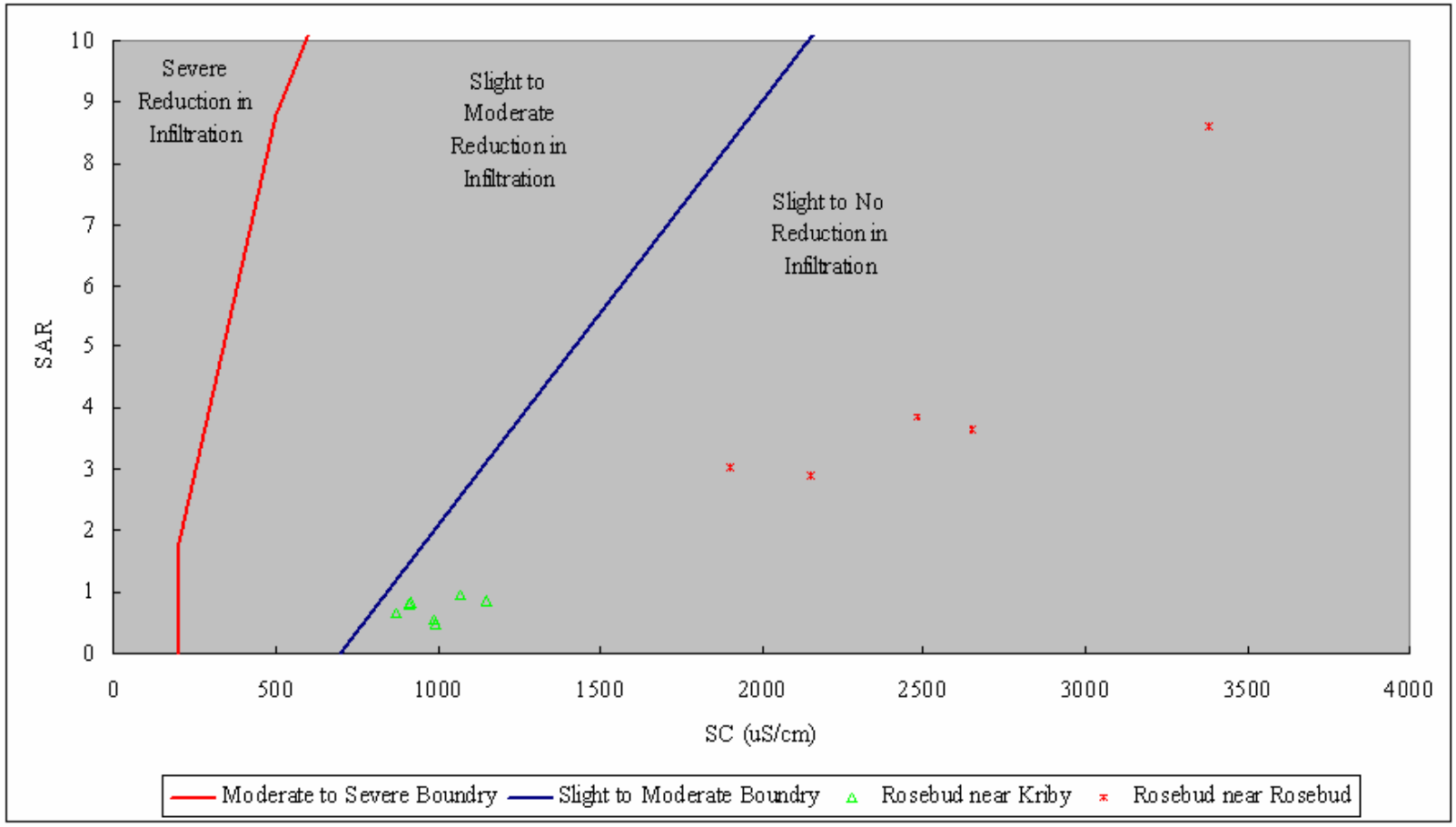

Figure 2 shows water quality data from water year 2006 in the Rosebud Creek Watershed compared to the infiltration criteria developed by Hanson et al. (1999). All values fall within the Slight to No reduction in infiltration field.

Figure 3: Rosebud Creek near Kirby

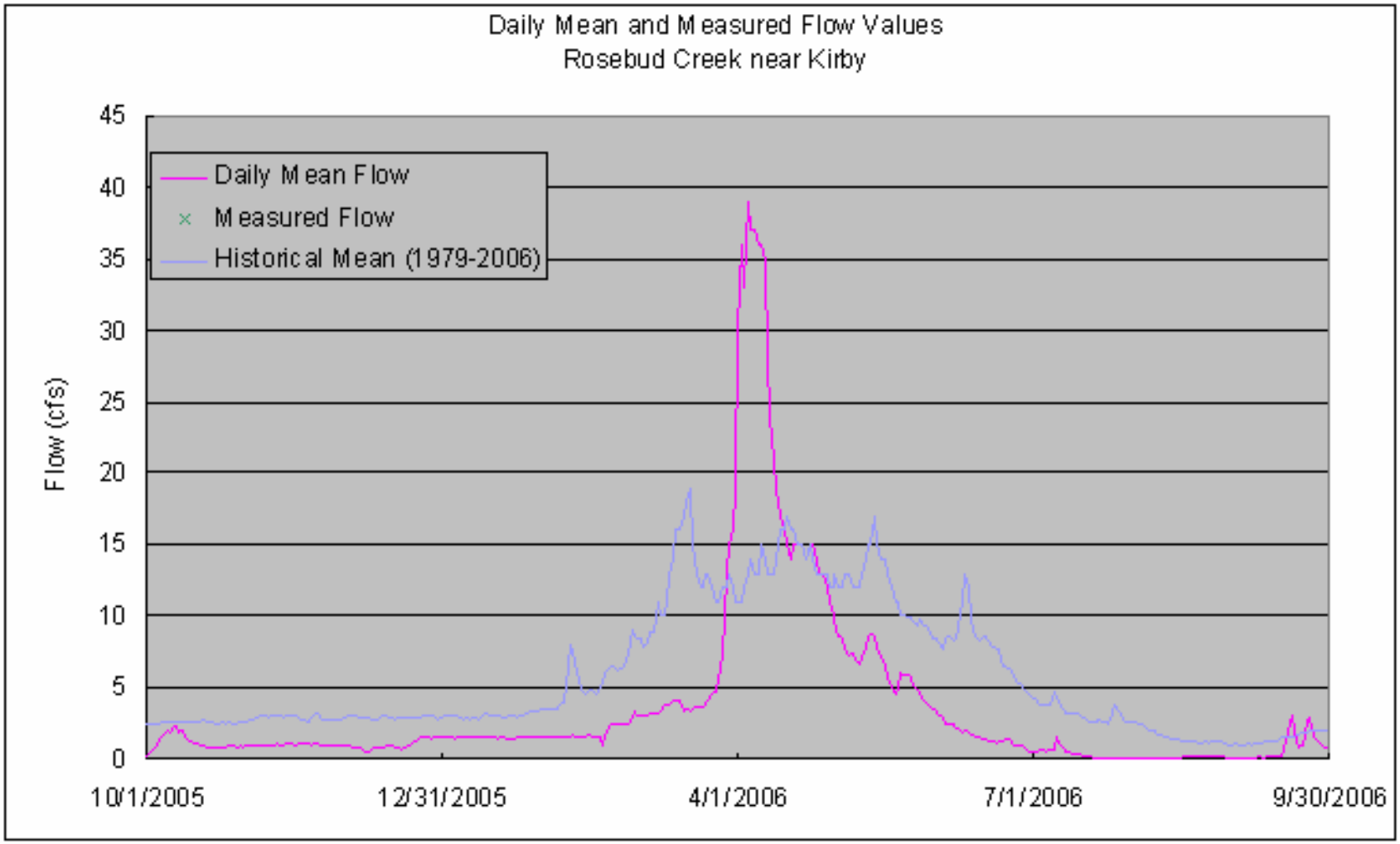

Figure 3 shows mean daily and field measurements of flow in a time series plot for water year 2006 for Rosebud Creek near Kirby. Mean daily flow values ranged from 0 to 39 cfs. The historical mean daily flow values are also shown to place the data in context.

Figure 4: Rosebud Creek near Kirby

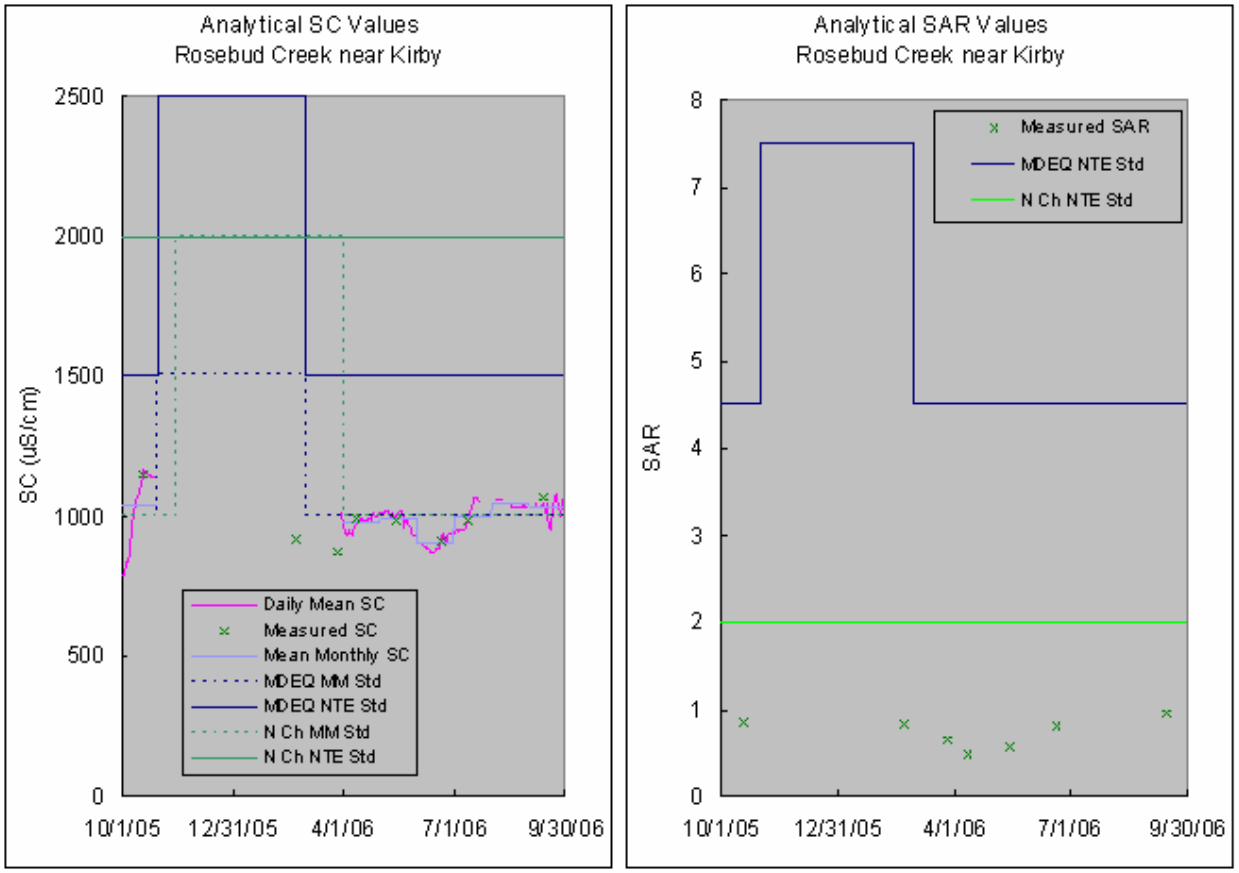

Figure 4 shows analytical and Daily Mean SC values (A) and analytical SAR values (B) in time series plots for water year 2006 for Rosebud Creek near Kirby. Mean Monthly SC values are also shown where more than nine samples were collected in a calendar month. SC values ranged from 794 uS/cm to 1170 uS/cm. SAR values ranged from 0.5 to 0.9. These values are compared to the instantaneous maximum and monthly mean standards developed by the MDEQ and the Northern Cheyenne Tribe. The monthly mean SC values were above the MDEQ and Northern Cheyenne monthly mean standard for EC during October, August and September. All other values were below the standards.

Figure 5: Rosebud Creek near Kirby

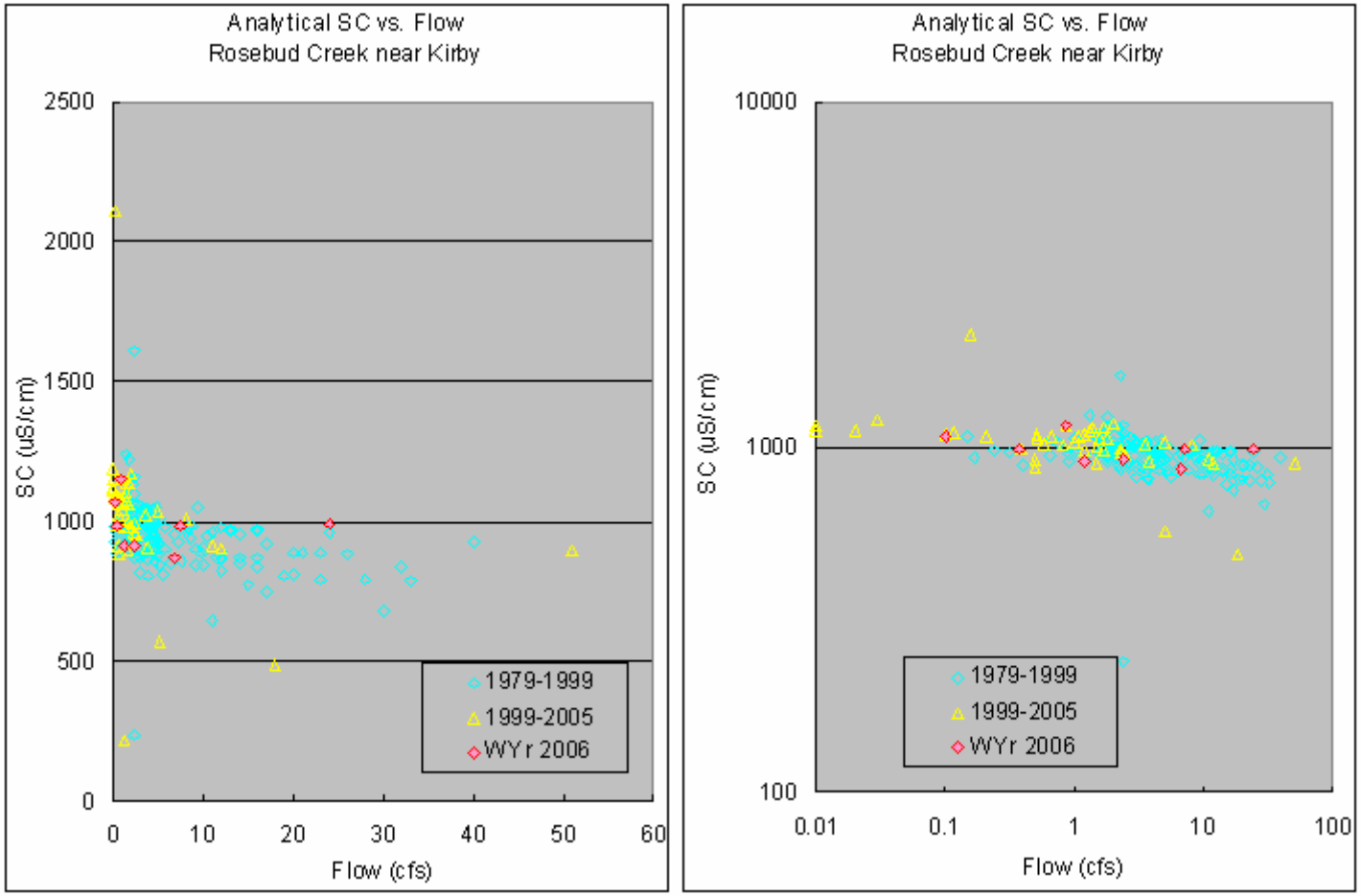

Figure 5 shows analytical SC vs. Flow data for water year 2006 for Rosebud Creek near Kirby. These data are charted on both linear (A) and logarithmic (B) scales. Historical SC vs. Flow data are also shown to place the data in context. It is believed that the narrow range of SC values collected at this site is reflective the relatively small drainage area above this station, and so the dominance of the groundwater signature.

Figure 6: Rosebud Creek near Kirby

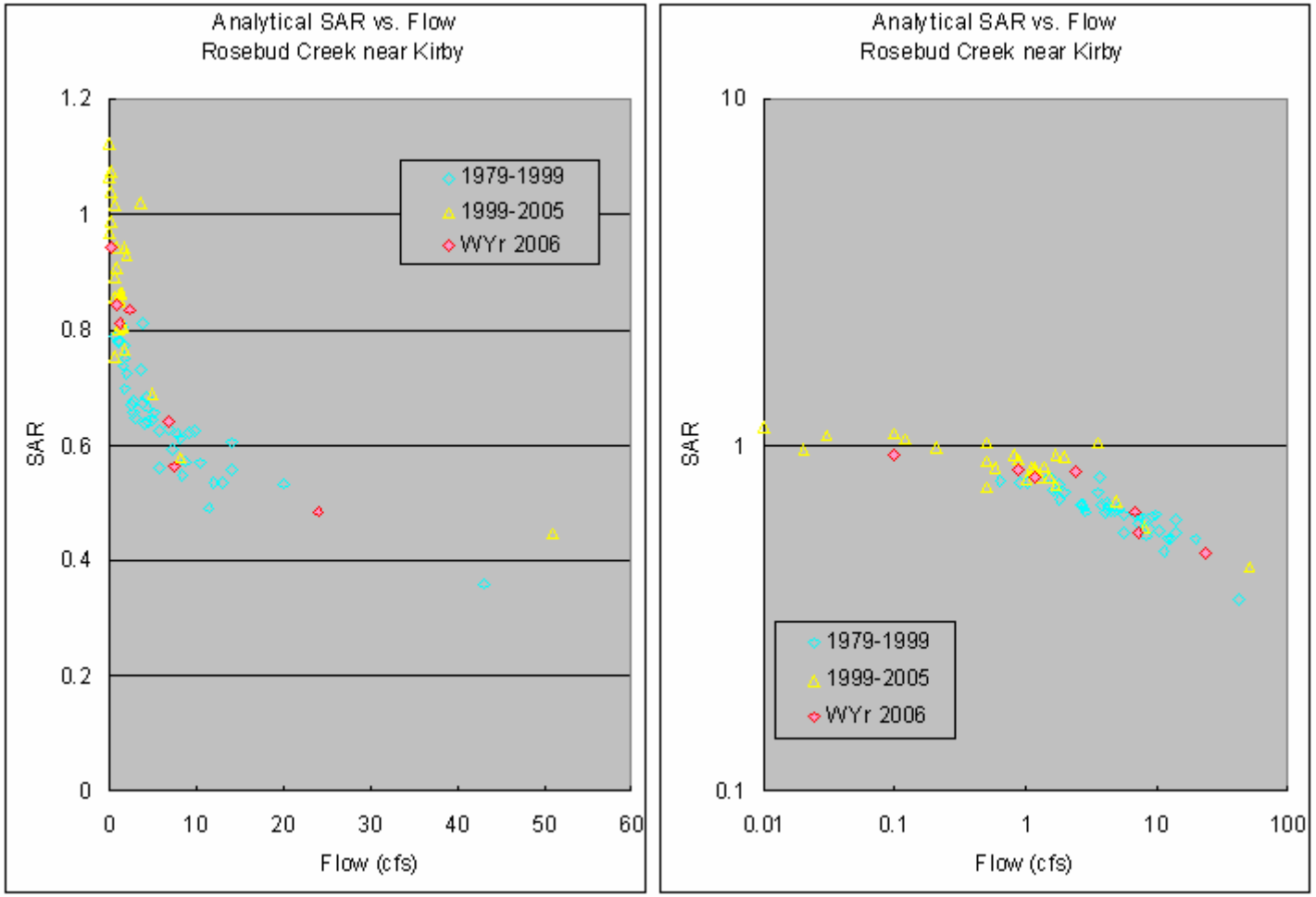

Figure 6 shows analytical SAR vs. Flow data for water year 2006 for Rosebud Creek near Kirby. These data are charted on both linear (A) and logarithmic (B) scales. Historical SAR vs. Flow data are also shown to place the data in context.

Figure 7: Rosebud Creek near Kirby

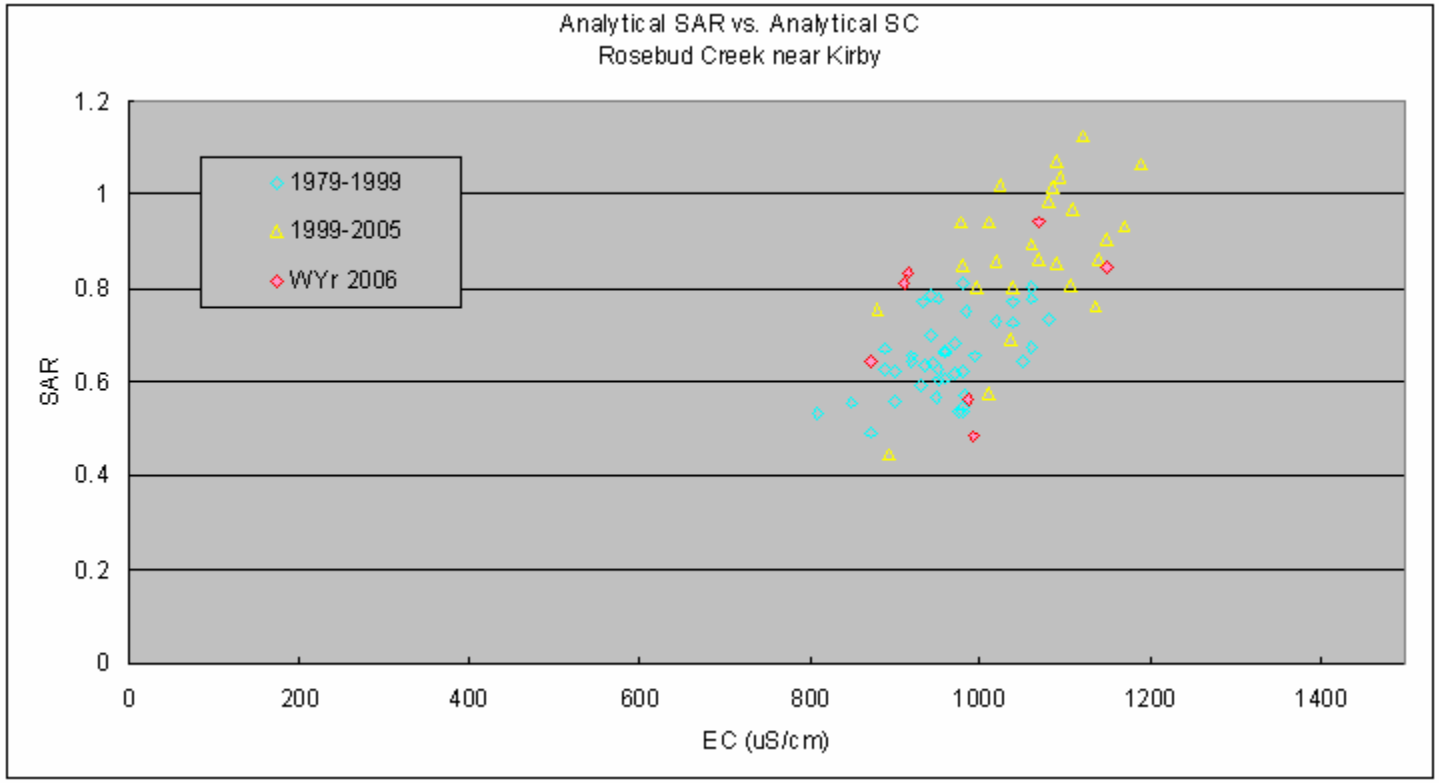

Figure 7 shows analytical SAR vs. analytical SC data for water year 2006 for Rosebud Creek near Kirby. Historical SAR vs. SC data are also shown to place the data in context.

Figure 8: Rosebud Creek near Colstrip

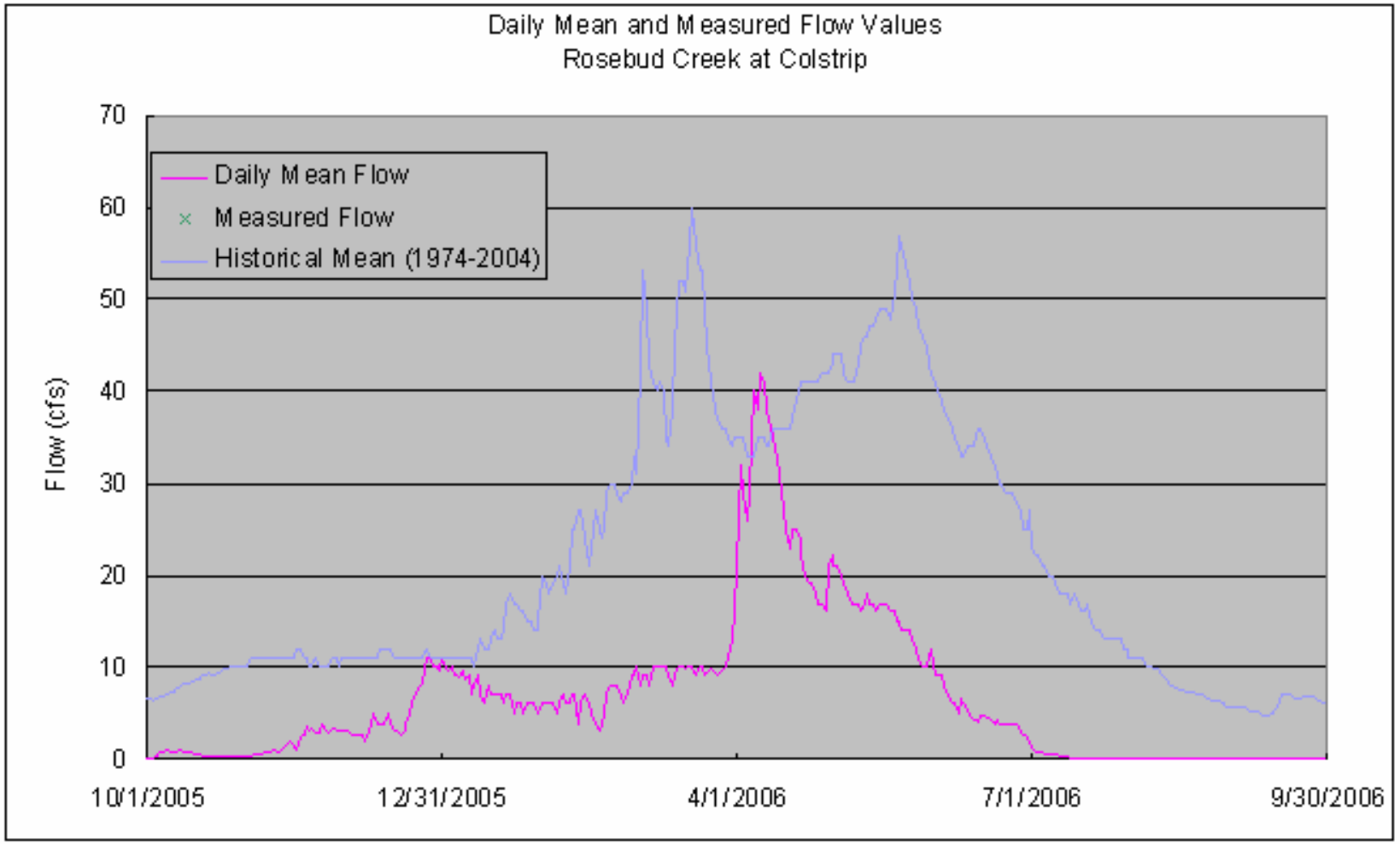

Figure 8 shows mean daily and field measurements of flow in a time series plot for water year 2006 for Rosebud Creek near Colstrip. Mean daily flow values ranged from 0 to 42 cfs. The historical mean daily flow values are also shown to place the data in context.

Figure 9: Rosebud Creek near Rosebud

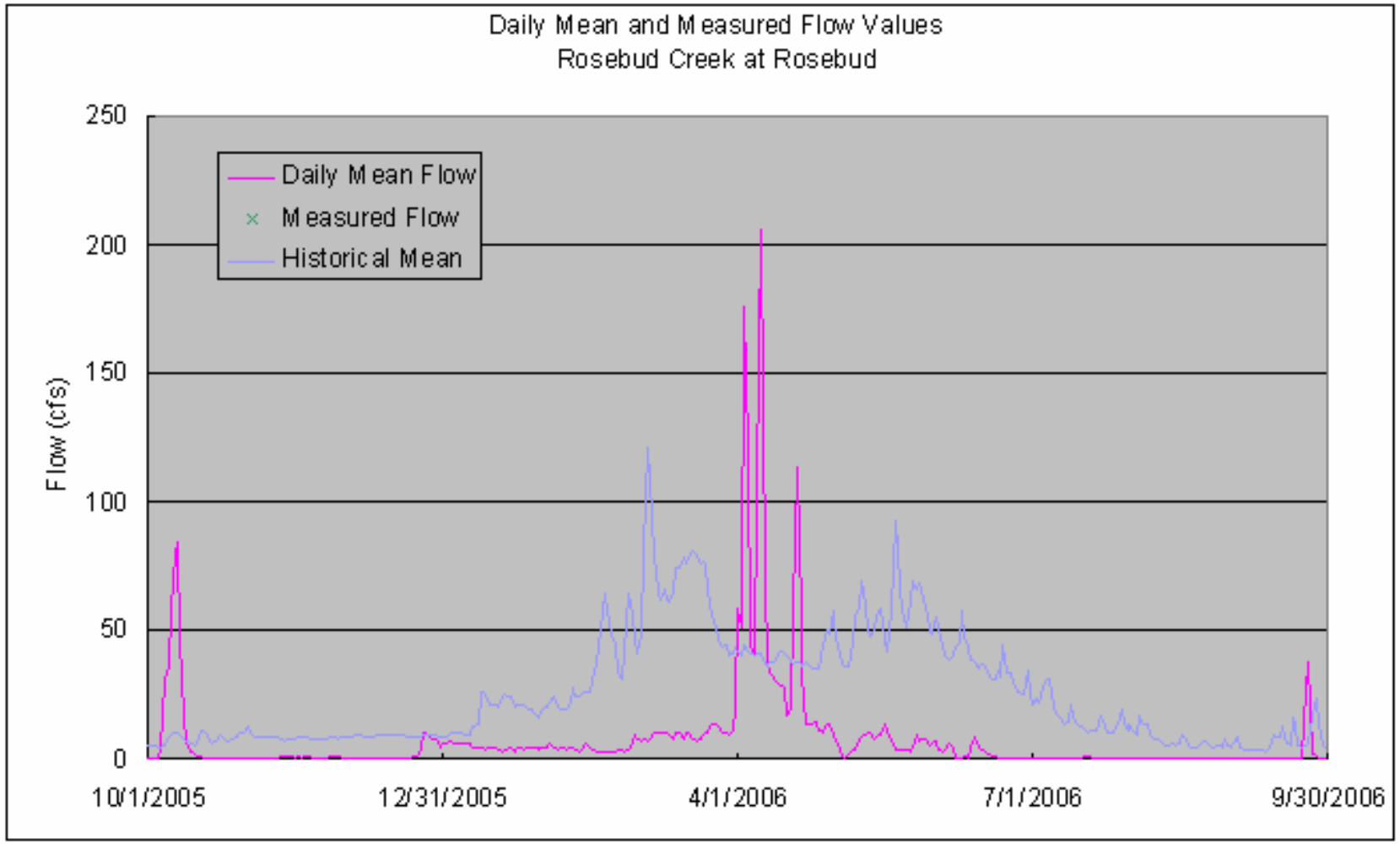

Figure 11 shows mean daily and field measurements of flow in a time series plot for water year 2006 for Rosebud Creek near Rosebud. Mean daily flow values ranged from 0 to 206 cfs. The historical mean daily flow values are also shown to place the data in context.

Figure 10: Rosebud Creek near Rosebud

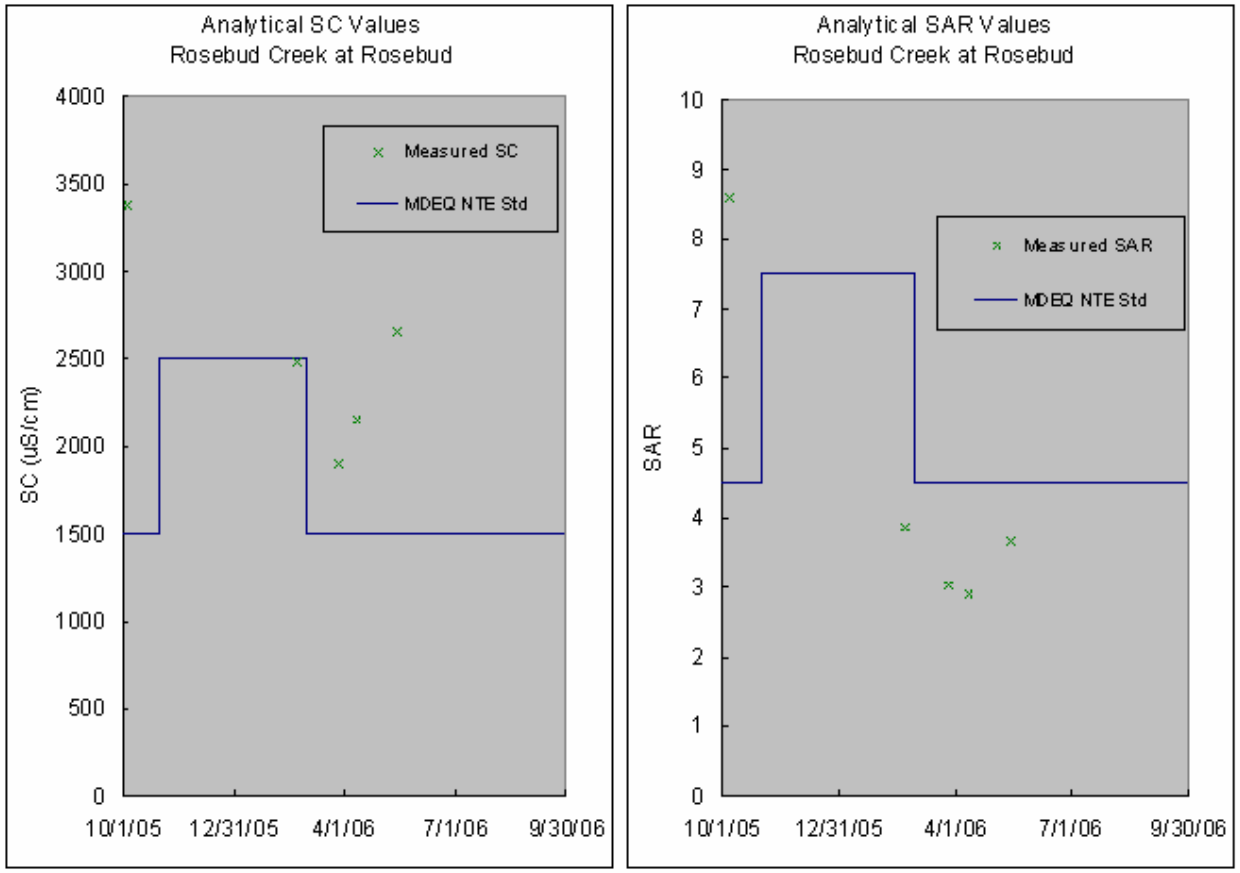

Figure 10 shows analytical SC values (A) and analytical SAR values (B) values in time series plots for water year 2006 for Rosebud Creek near Rosebud. SC values ranged from 1900 to 3380 uS/cm. SAR values ranged from 2.9 to 8.6. These values are compared to the not to exceed standards developed by the MDEQ. The measured SC values were above the MDEQ standard for four of the five samples. The measured SAR values were below the MDEQ standard for four of the five samples.

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Figure 11: Rosebud Creek near Rosebud

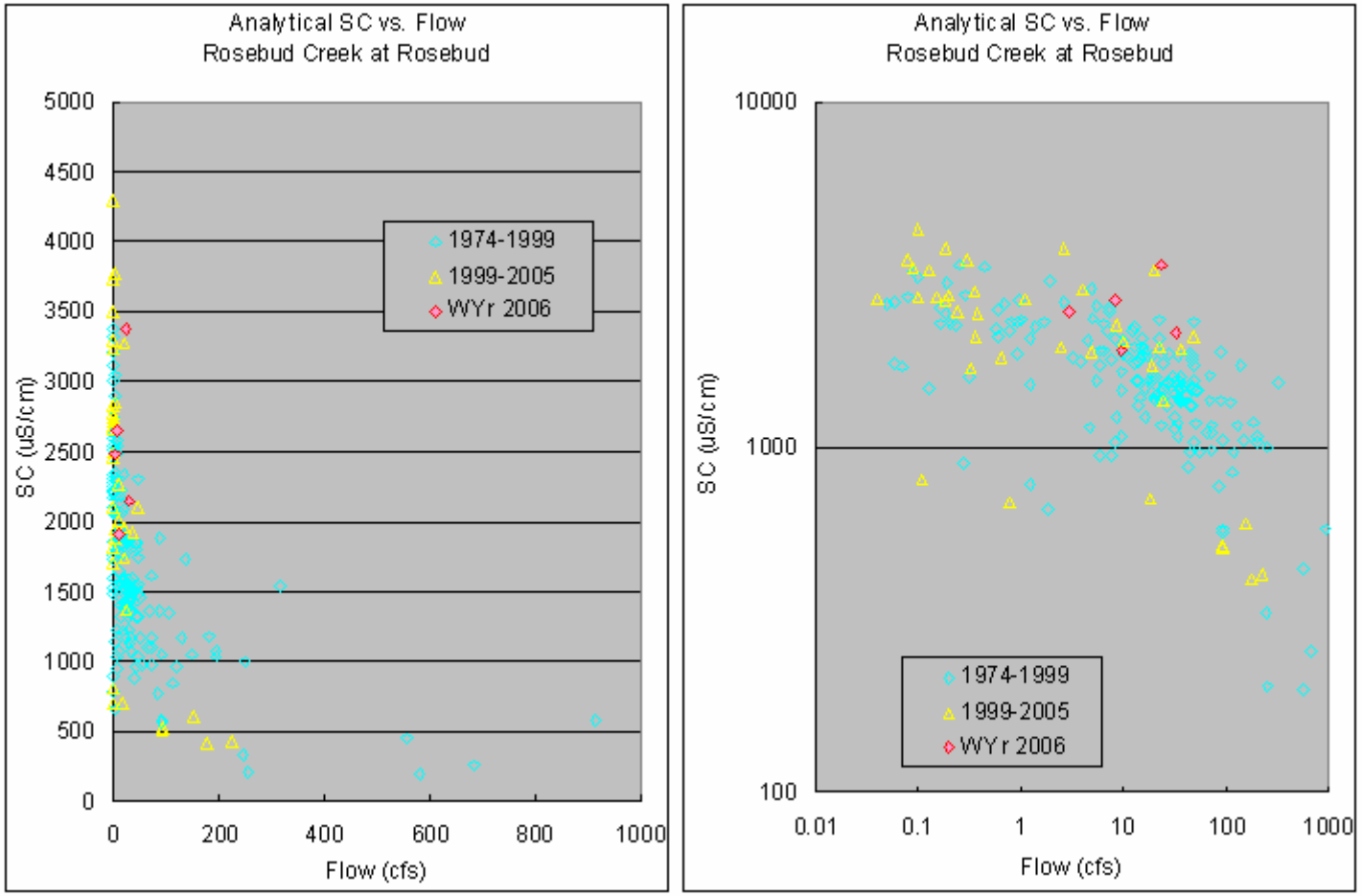

Figure 11 shows analytical SC vs. Flow data for water year 2006 for Rosebud Creek near Rosebud. These data are charted on both linear (A) and logarithmic (B) scales. Historical SC vs. Flow data are also shown to place the data in context.

Figure 12: Rosebud Creek near Rosebud

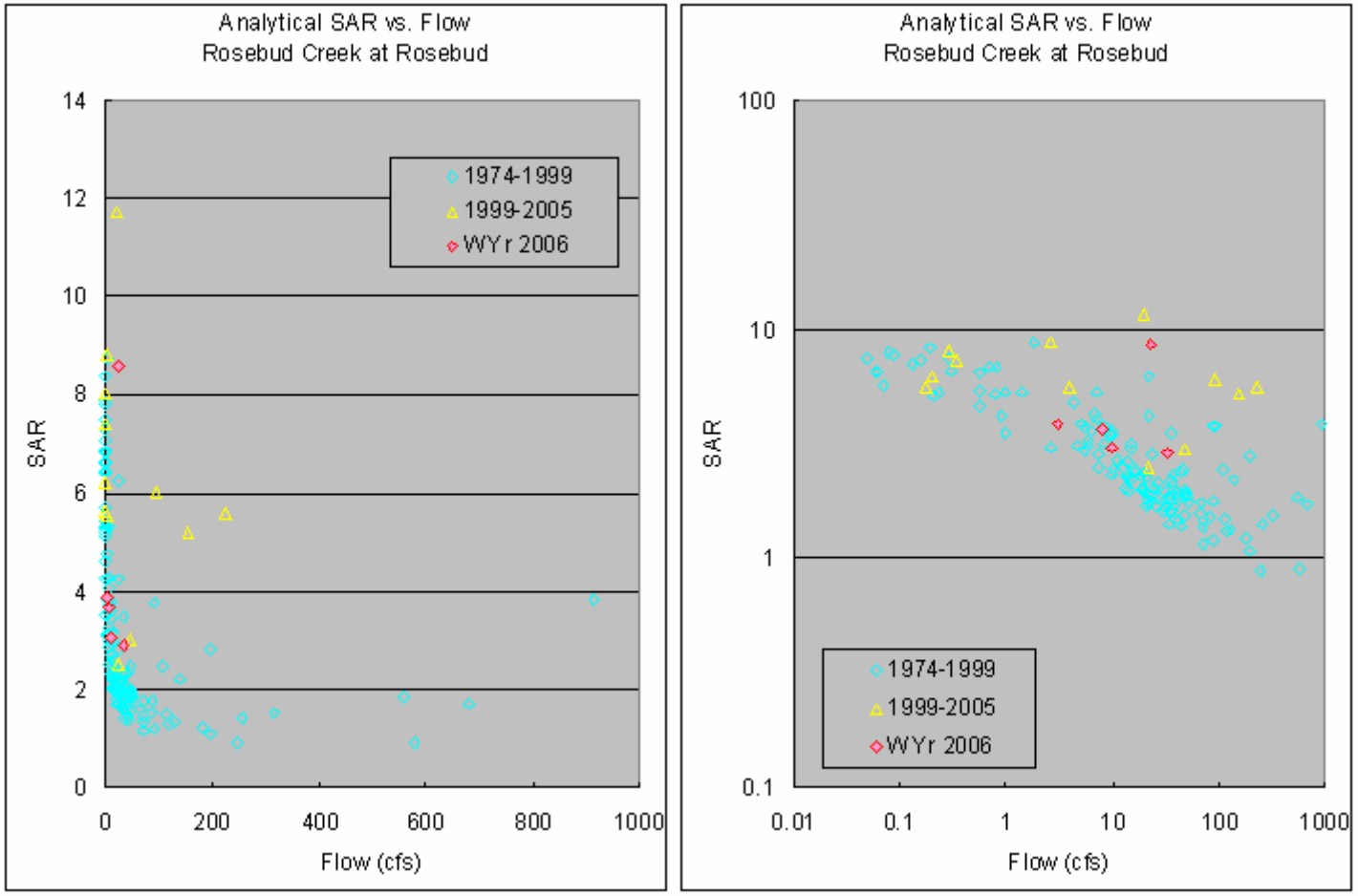

Figure 12 shows analytical SAR vs. Flow data for water year 2006 for Rosebud Creek near Rosebud. These data are charted on both linear (A) and logarithmic (B) scales. Historical SAR vs. Flow data are also shown to place the data in context.

Figure 13: Rosebud Creek near Rosebud

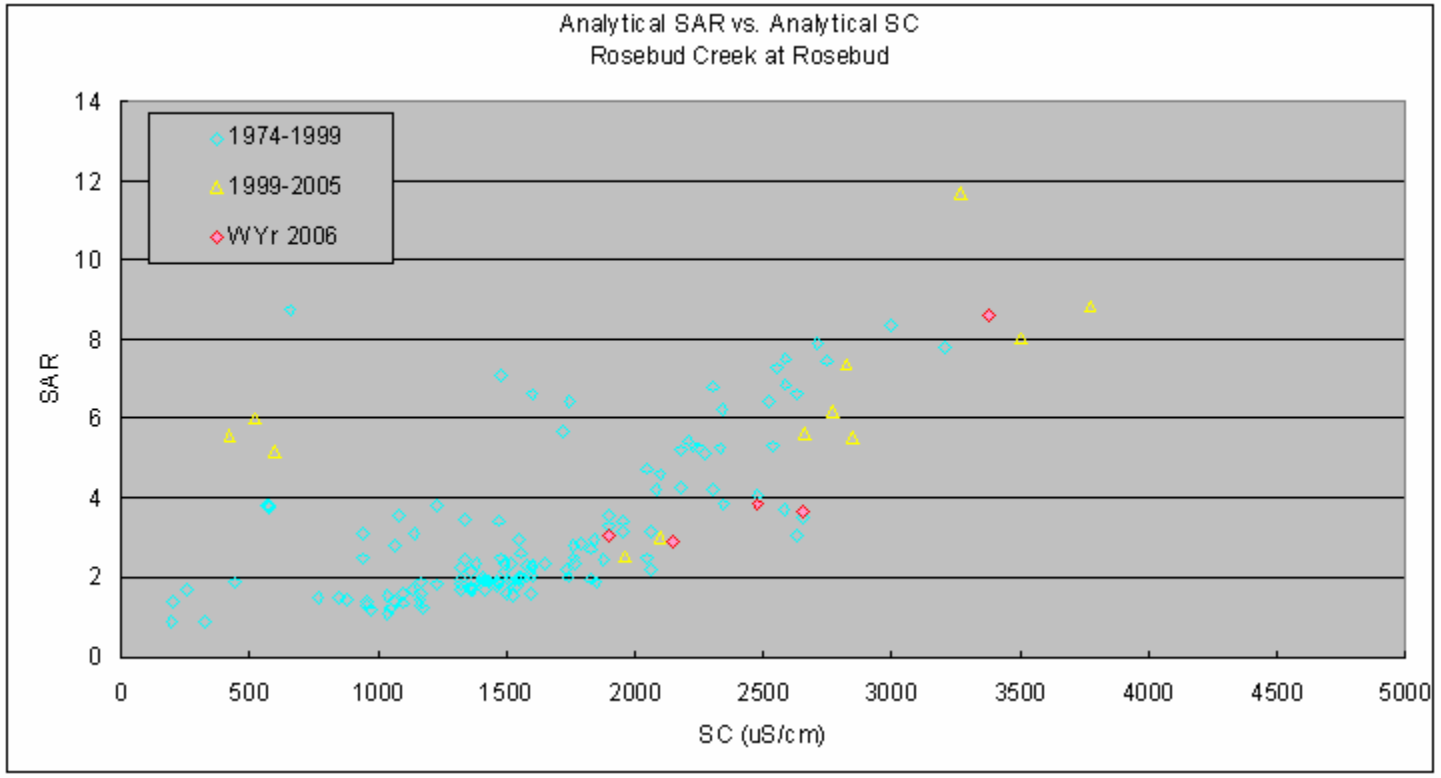

Figure 15 shows analytical SAR vs. analytical SC data for water year 2006 for Rosebud Creek near Rosebud. Historical SAR vs. SC data are also shown to place the data in context.